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COMPUTER USE IN RESOURCE EVALUATION - CANMET'S SYSTEM FOR MINERAL RESERVE EVALUATION

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ABSTRACT

COMPUTER USE IN RESOURCE EVALUATION

CANMET'S SYSTEMS FOR MINERAL RESERVE EVALUATION

Two computer program systems have been created by the Mine Evaluation Group (MEG) of MRL, CANMET, EMR, since 1975, for the purpose of reserves evaluation. These systems were developed principally for the evaluation of uranium reserves but can also be used to evaluate other mineral resources.

The CADD system (Coding and Analysis of Drillhole Data) is used to code, edit and prepare basic drillhole data to be used subsequently for the evaluation of reserves. The GEM system (Geostatistical Evaluation of Mines) is a group of computer programs allowing variogram analyses and kriging estimations.

The CADD and GEM systems include twenty-five FORTRAN and COBOL computer programs which can: prepare drill log reports; calculate economical composite intersections; draw projections of drillholes on sections or plans; calculate experimental variograms; find the best theoretical model; perform kriging evaluations as well as conventional type evaluations; and draw isocurves.

The CADD and GEM Systems for Mineral Reserve Evaluation are now available to the public on a magnetic tape at a cost of five hundred dollars ($500) (Canadian).

BIOGRAPHICAL NOTE

Raymond Sabourin is the geostatistician for the Mine Evaluation Group of the Mining Research Laboratories of CANMET, EMR. He has evaluated several uranium and coal deposits in Canada since he joined the Mine Evaluation Group in 1975, and has participated very actively in the realization and documentation of CANMET's systems for mineral reserve evaluation. He is presently pursuing PH.D. research studies in resource evaluation at the University of Ottawa.

RÉSUMÉ

UTILISATION DE L'ORDINATEUR POUR L'ÉVALUATION DES RESSOURCES
SYSTÈMES CANMET POUR L'ÉVALUATION DES RESERVES MINÉRALES

Deux systèmes de programmes ont été créés par le Groupe d'Evaluation Minière des LRM, CANMET, ÉMR, depuis 1975, dans le but d'évaluer les réserves minérales. Ces deux systèmes furent développés principalement pour l'évaluation des réserves d'uranium mais ils peuvent aussi être utilisés pour évaluer d'autres ressources minérales.

Le système CADD (Coding and Analysis of Drillhole Data) est utilisé pour codifier, éditer et préparer les données de base de sondages qui seront subséquemment utilisées pour l'évaluation des réserves. Le système GEM (Geostatistical Evaluation of Mines) est un groupe de programmes permettant l'analyse des variogrammes et une évaluation des réserves par les méthodes géostatistiques.

Les systèmes CADD et GEM comprennent vingt-cinq programmes FORTRAN et COBOL qui peuvent préparer des rapports sur les sondages, calculer des intersections économiques le long de sondages, dessiner les projections de sondages sur des sections ou des plans, calculer les variogrammes expérimentaux, trouver le meilleur modèle théorique du variogramme, utiliser les méthodes géostatistiques d'évaluation aussi bien que les méthodes traditionnelles, et tracer des isocourbes.

Les systèmes CADD et GEM pour l'évaluation des réserves minérales sont maintenant disponibles au public sur bande magnétique au coût de cinq cents dollars (500$) en argent canadien.

NOTE BIOGRAPHIQUE

Raymond Sabourin est geostatistien du Groupe d'Evaluation Minière (MEG) des Laboratoires de Recherches Minières de CANMET, EMR. Il a évalué plusieurs gisements d'uranium et de charbon au Canada depuis qu'il s'est joint au groupe MEG en 1975, et a participé très activement à la réalisation et à la documentation des Systèmes CANMET pour l'Evaluation des Réserves Minérales. Il complète présentement des recherches en évaluation des ressources, en vue d'obtenir un doctorat à l'université d'Ottawa.

COMPUTER USE IN RESOURCE EVALUATION

CANMET'S SYSTEMS FOR MINERAL RESERVE EVALUATION

HISTORICAL DEVELOPMENT

Computer utilization by earth science professionals, and more particularly those evaluating resources has been progressive but slower than in other fields of applied sciences. This is so because often the problems to be solved were unique, complex, and moreover, involved the use of large amounts of data. The software was either not available or very scattered and the memory of available computers was too small to handle their problems. The geologists and mining engineers were looking at an interesting tool which was mainly used by others. The fantastic computer technological developments have progressively made it possible for groups like the Mine Evaluation Group (MEG), CANMET, EMR, to create software which can perform an increasing number of tasks related to mineral resources* evaluation.

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* Definitions of resources and reserves: Resource estimates refer to quantities of a commodity contained in ore mineable at given prices (i.e., ore recoverable by mining, with due consideration of ore dilution). Reserves refer only to those measured and indicated resources that could be mined at the market price as determined at the time of the assessment.

MEG is a group of professional Geologists, Mining Engineers, Geostatisticians and Programmers, created in 1974 as part of the Mining Research Laboratories (MRL) of Energy, Mines and Resources, Canada. MRL is one of the research laboratories of the Canadian Center for Mineral and Energy Technology (CANMET). One objective* of MEG is to evaluate the Reasonably Assured Uranium Resources in Canada. MEG is also involved in reserve evaluation of the Southern Saskatchewan lignite deposits. MEG developed software mainly to evaluate uranium resources, but the same computer programs can also be used to evaluate other mineral resources.

Two computer program systems are described in this report. The CADD system (Coding and Analysis of Drillhole Data) was developed to code and edit (i.e., correct and prepare) drillhole data which can subsequently be used for the evaluation of the resource. The GEM system (Geostatistical Evaluation of Mines) was developed

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*Uranium in Canada 1980 Assessment of Supply and Requirements, Appendix 2, p 30. "Primary responsibility for the work of the subcommittee on Reasonably Assured Resources resides with the Mine Evaluation Group. The subcommittee on Reasonably Assured Resources is responsible for (a) auditing the measured and indicated resources in Canadian uranium deposits mineable under current technological conditions in given price ranges, and (b) assessing the levels of Canadian uranium production that could be supported by the deposits".

to evaluate resource quantities using geostatistical methodologies, as well as other more traditional resource evaluation methodologies.

The creation of these two systems of computer programs started more or less simultaneously. The CADD system was fully operational as early as the end of 1975 and was used to code, edit and copy on a magnetic tape more than 1000 sets of drillhole data of one of the most important uranium deposits in Canada. The computer programs of the GEM system existing at that time, however, mainly helped MEG geologists in evaluating uranium resources using the more traditional methods. For example, the purpose of the first computer program of the GEM system was to define composite intersections along drillholes using economical and mining criteria. This program is performing an essential task in resource evaluation and can be used by any evaluation method. Today, it would be difficult for MEG staff to work without it. Progressively more GEM programs were created which perform time consuming but important tasks, otherwise performed by MEG's geologists. In addition, geostatistical programs were created and used for the resource evaluation of the main uranium deposits in Canada. To our knowledge, in 1975, no complete system of resource evaluation was available on the market, and we had to create programs related specifically to MEG's working effort.

The CADD and GEM computer programs are documented by twenty five CANMET divisional reports. The general organization of the documentation is identical from one report to the other and includes a general description of the program, a description of the

various options as well as certain variables used within the program, and a definition of array dimensions and of the input-output logical units. In addition, each report includes an example of a program execution using specific options and a fictitious data set. The documentation of the CADD and GEM systems would not have been complete without a guide for coding drillhole data and a report (this report) describing in general terms the two systems. The guide for coding drillhole data defines each variable on four coding sheets (Fig. 1A, 1B, 1C and 1D) as well as some codes specially used by MEG. This guide also gives several coding examples of drillholes using fictitious data. They are the same fictitious data used by some CADD and GEM programs to provide a test example of their execution.

CADD SYSTEM

As mentioned, the purpose of the CADD system is to code and edit drillhole data. This system is really a data base management system using sequential files. Sequential files were preferred to random indexed files because:

1. drillhole data were complete when received;
2. the amount of drillhole data per file, with a few exceptions, was not excessive to be handled by sequential files; and
3. all available drillhole data were used most of the time.

The coding, correction and preparation of drillhole data always represents an important part of the work perfomed by MEG's geologists. These tasks can take up to fifty per cent of the time

available to complete an evaluation. They must be done by specialized staff because any errors, for example, on drillhole coordinates, core segment grades, drillhole orientation or rock description, if not detected and corrected, can easily be the cause of erroneous evaluations. Errors in the basic data and coding errors can easily be identified by a computer program but the geologist should always visually inspect the data. The geologist should never think that his file is free of errors. Even so, files in which the majority of errors have been corrected, will have to be used.

Like in most computer systems the programs of the CADD and GEM systems usually create a file which can be used subsequently by another program. For example, in Fig. 2, programs MEG1600, MEG1500 and MEG1010 must read a file created by MEG1000. In turn, MEG1000 must read a file created by MEG0401, etc.

The most important programs of the CADD system are: MEG1000, MEG1600 and MEG1500. The first two programs create an identical master file which will be used by several GEM programs as well as program MEG1500 and by some utilitarian programs of the CADD system. The purpose of program MEG1000 is to define and to compute new variables from the basic data already sorted by program MEG0401. Some of the new variables are: the coordinates at the beginning of each core segment; the vertical, horizontal or true segment projections, considering their orientations, their lengths, as well as the dip and azimuth of the geological formation. Program MEG1600 creates a master file identical to MEG1000, except that combined drillholes are allowed. Program MEG1500 uses

either MEG1000 or MEG1600's master file to produce detailed geological reports similar to those normally prepared by a geologist.

The other CADD programs are utilitarian and make it possible to sort, correct and edit the basic coded data of MEG0401 files, as well as MEG1000 or MEG1600 master files. For example, the only purpose of program MEG0401 is to sort basic coded data. MEG0410 verifies the numerical or alphanumerical type of each variable and program MEG0411 finds coding errors by comparing the coded numerical values to establish variation limits. Program MEG1010 selects drillholes and creates a sub-file from the MEG1000 or MEG1600 master file.

The future utilization of micro and mini computers will enable us to replace most of the utilitarian CADD programs with several interactive programs. MEG also plans to create an interactive data coding program which would eliminate manual coding presently in use.

GEM SYSTEM

Some programs of the GEM system can be used by geostatistical and other types of methods. The programs of the GEM system will thus be described in relation to their utilization by different evaluation methodologies. These methods are identified in Table (1) as: geometrical methods (sectional or polygonal), moving average or inverse distances methods, and finally geostatistical methods. Evaluations made on tabular (2-D) deposits have been distinguished from the evaluations made on all other types of deposits (3-D).

Regardless of the method of evaluation, MEG1000 or MEG1600 master files will always be used first. The programs of the GEM system are divided into four groups. The first group includes three programs (MEG0100, MEG2010 and MEG3000) which define composite intersections along drillholes, group together drillhole composite intersections, and draw projections of drillhole core segments on sections or plans respectively. The second group includes three programs (MEG2040, MEG2050 and MEG2055) which define new equal length segments along drillholes, gather these new segments within regular blocks and estimate the average grade of the blocks, using a moving average or an inverse distance weighting method respectively. The third group includes five programs (MEG2100, MEG2200, MEG2250, MEG2275 and MEG2350) of which MEG2350 is not available to the public. These programs calculate the basic statistics of evaluated variables, analyze the relationship between these variables, compute experimental variograms of two or three dimensional variables, as well as their average trends, define generalized covariances, theoretical variograms and the polynomial coefficients of the trend. The fourth group also includes five programs (MEG2300, MEG2350, MEG2400, MEG2500 and MEG2560) of which two (MEG2350 and MEG2500) are not available to the public. These programs evaluate points, blocks or polygons using different types of geostatistical methods of estimation (kriging), establish an inventory of reserves according to the level of confidence about their existence (measured, indicated and inferred resources) and finally draw isocurves.

GEOMETRICAL METHODS

The GEM programs used by geometrical methods are MEG0100 and MEG3000. Once the data has been coded and MEG1000's master file prepared, the geologist will run MEG0100 to define composite intersections along drillholes (Fig. 3), unless the polygonal method on a non-tabular deposit is used. In this case, the geologist will define equal length segments along drillholes using program MEG2040. In every case, program MEG3000 will be used to show the position of drillholes and their composite intersections on sections or plans (Fig. 4 and 5). The isocurve programs can be used only if drillholes are distributed regularly.

MOVING AVERAGE METHODS

For the purpose of discussion, the inverse distance method will be considered as a moving average method. Normally, two-dimensional variables are defined for tabular or strata-bound deposits and, in this case, programs MEG0100 and MEG2010 will have to be used. Program MEG2010 gathers together composite intersections along drillholes, which were previously defined by MEG0100. Programs MEG2050 and MEG2055 are run to evaluate the average grade of regular blocks using a simple moving average method. MEG2055 gives graphics showing the tonnage, the amount of metal and the average grade of the deposit in relation to cut-off grades specified by the user. This program also produces a map identifying the mineralization contours. The average block grade, the tonnage and amount of metal are given for each block within the mineralization limits.

GEOSTATISTICAL METHODS

This discussion will be limited to a three-dimensional evaluation. In the simplest case, only one variable (the average grade of a block) will be evaluated. The geologist will first define equal length segments using MEG2040. It is then possible to calculate three-dimensional experimental variograms, using programs MEG2200 and MEG2250. In addition, these two programs study the relationship between local variances and local means (a proportional effect study). The relationship is necessary to calculate relative experimental variograms. Once all experimental variograms are calculated, a theoretical variogram model can then be defined by MEG2275 or MEG2350.

The average grade of regular blocks or polygons can be evaluated by program MEG2300. This program uses several kriging methods such as: lognormal, universal and random kriging. MEG2300 prints the estimated average grades of blocks and their kriging variances in such a way as to create a map to a certain scale.

Programs MEG2500 or MEG2560 are used for isocurve tracing (Fig. 6). Finally, the resource evaluation would not be complete without an inventory of the resource. The classification of a resource by the level of certainty of its existence can be done using the kriging variance of average block grades. Reserves are then calculated using economical parameters and technological factors, such as a cut-off and a dilution grade, dilution rate and a recovery percentage related to the efficiency of the mining method.

FUTURE PROJECTS

Future projects involving utilization of the computer by the MEG group, are divided into two groups. The first group of projects will mainly involve completion of a new system of programs in addition to the CADD and GEM system, such as a system for the evaluation of coal resources. MEG intends, however, to use more and more already marketed systems, such as: systems for economic evaluation of a mineral deposit or systems for the cost modelling of mining operations. These private systems, if used by MEG, will have to meet high security standards. In addition, the renting or borrowing costs of these systems should be reasonable. MEG may also give program development contracts. In this case these programs would still be available to the public. Any new computer program will be developed in relation to the needs and objectives of MEG. However, computer program development suggested by the mining community will be welcomed.

The second group of projects will constitute improving already existing programs by: adapting them, for example, to Fortran level 5, running them with micro computers, or modifying them so that they can be used with other main frame computers (IBM, HP, Digital). All these projects could be contracted out, or performed by MEG staff. The results of these projects will all be made available to the public.

AVAILABILITY OF THE CADD AND GEM SYSTEMS

Twenty-five technical reports have been written in addition to the basic data coding guide, and the present report. All

these reports are available to the public on microfiche or photocopies by Micro-Media Services. The source deck of the CADD and GEM programs and the test data, are also available on a single magnetic tape at a cost of $500.00 (Canadian). The Technology Information Division of CANMET and its Technical Inquiries and Documentation Section will inform the public about the availability of the reports, the distribution procedure, as well as the payment details for the magnetic tape.

CANMET may organize in Ottawa a limited number of seminars to demonstrate the use of these systems, if there is a sufficient interest by prospective users.

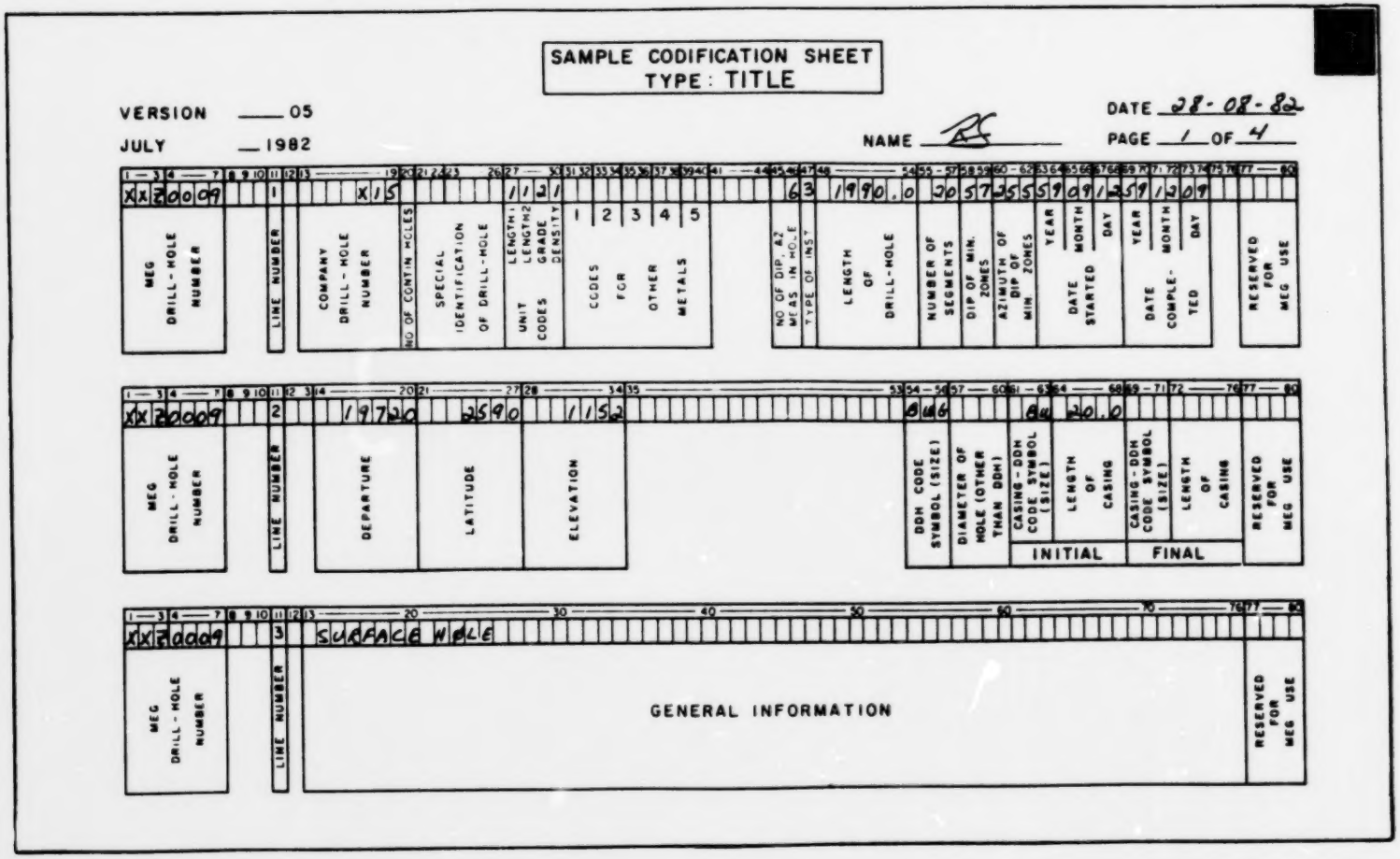


Fig. 1a - CADD system coding sheets - title sheet

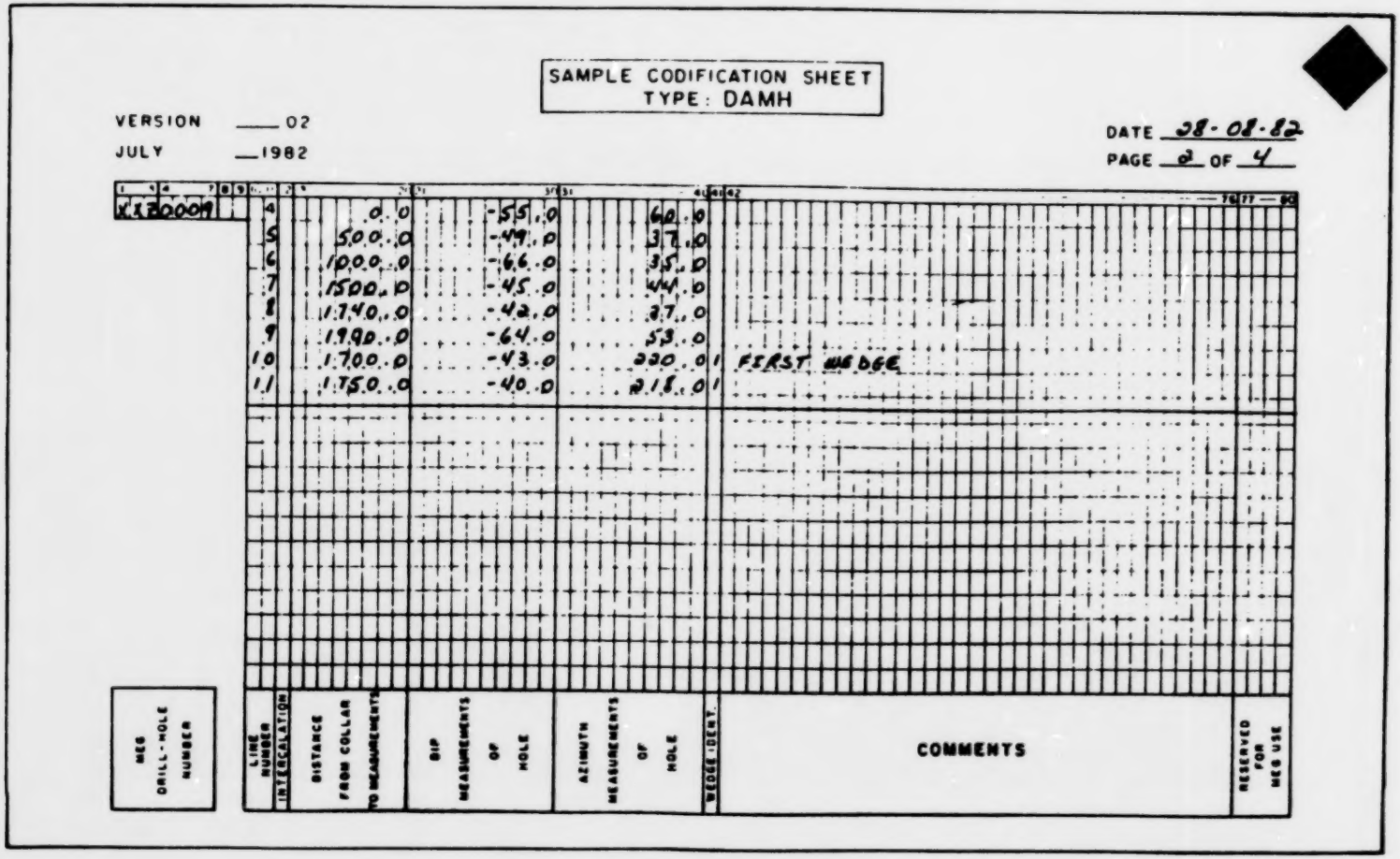


Fig. 1b - CADD system coding sheets - sheet for dip and azimuth measurements of hole

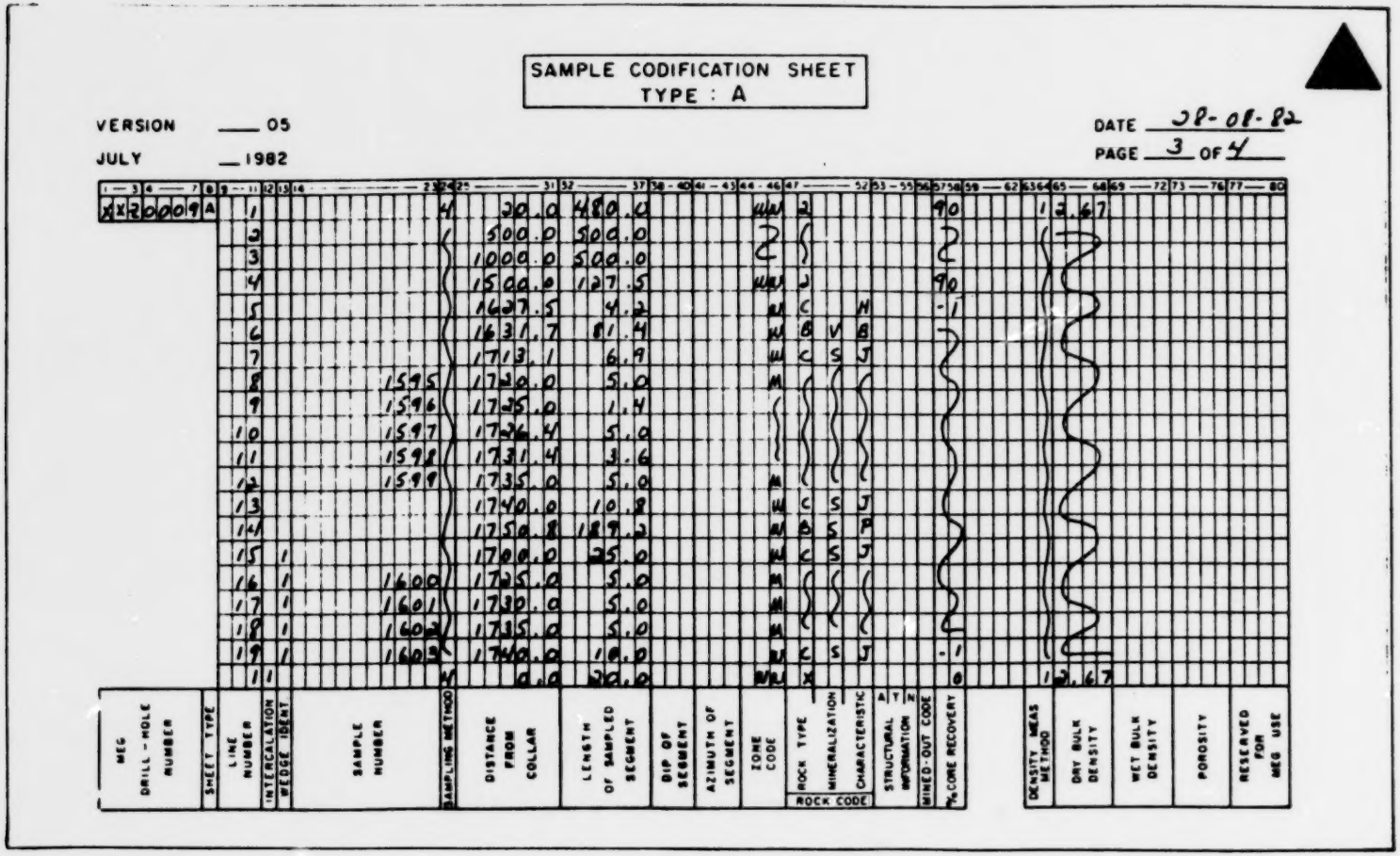


Fig. 1c - CADD system coding sheets - type a sheet - geological information

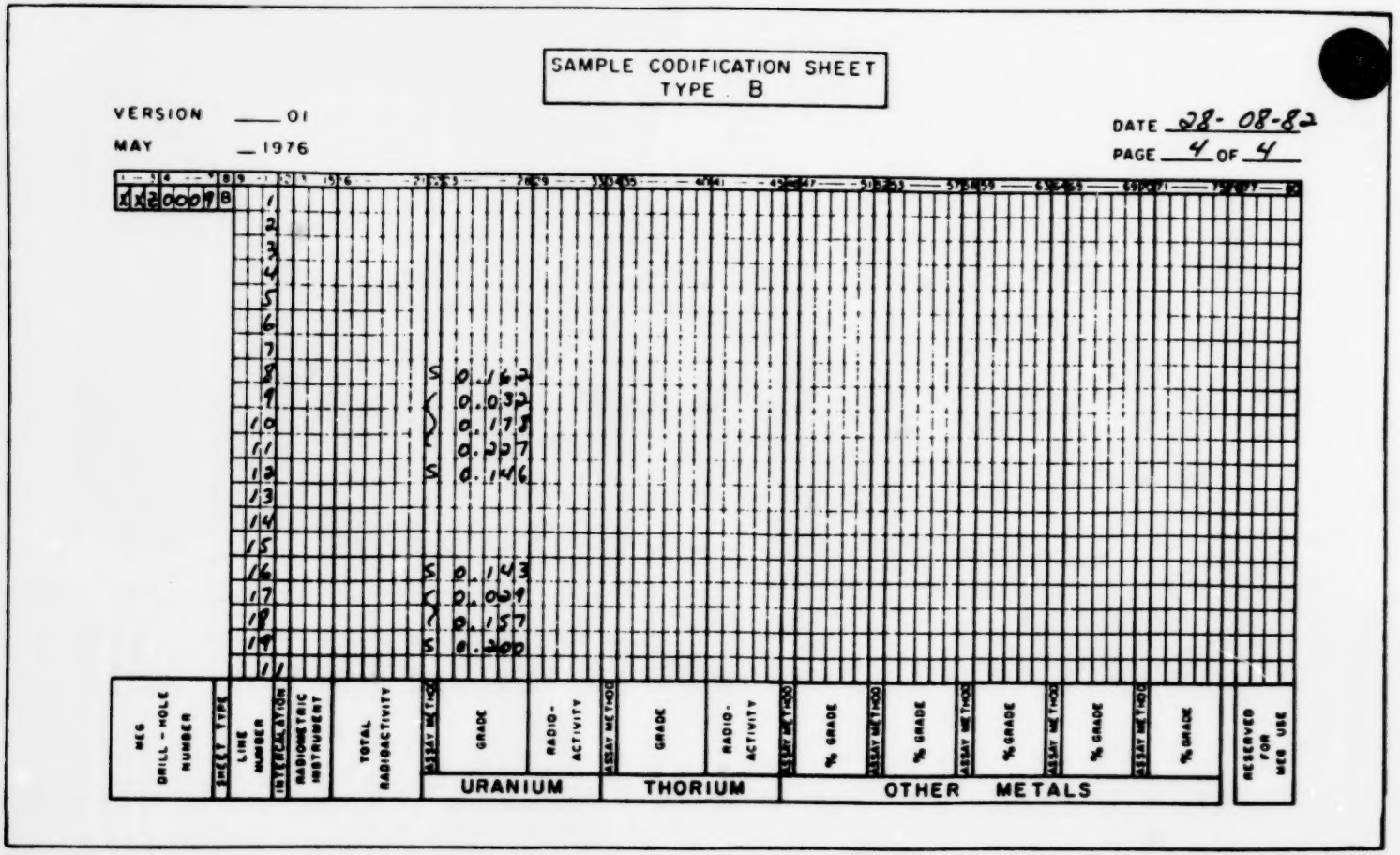


Fig. 1d - CADD system coding sheets - type B sheet - analysis sheet

C A D D

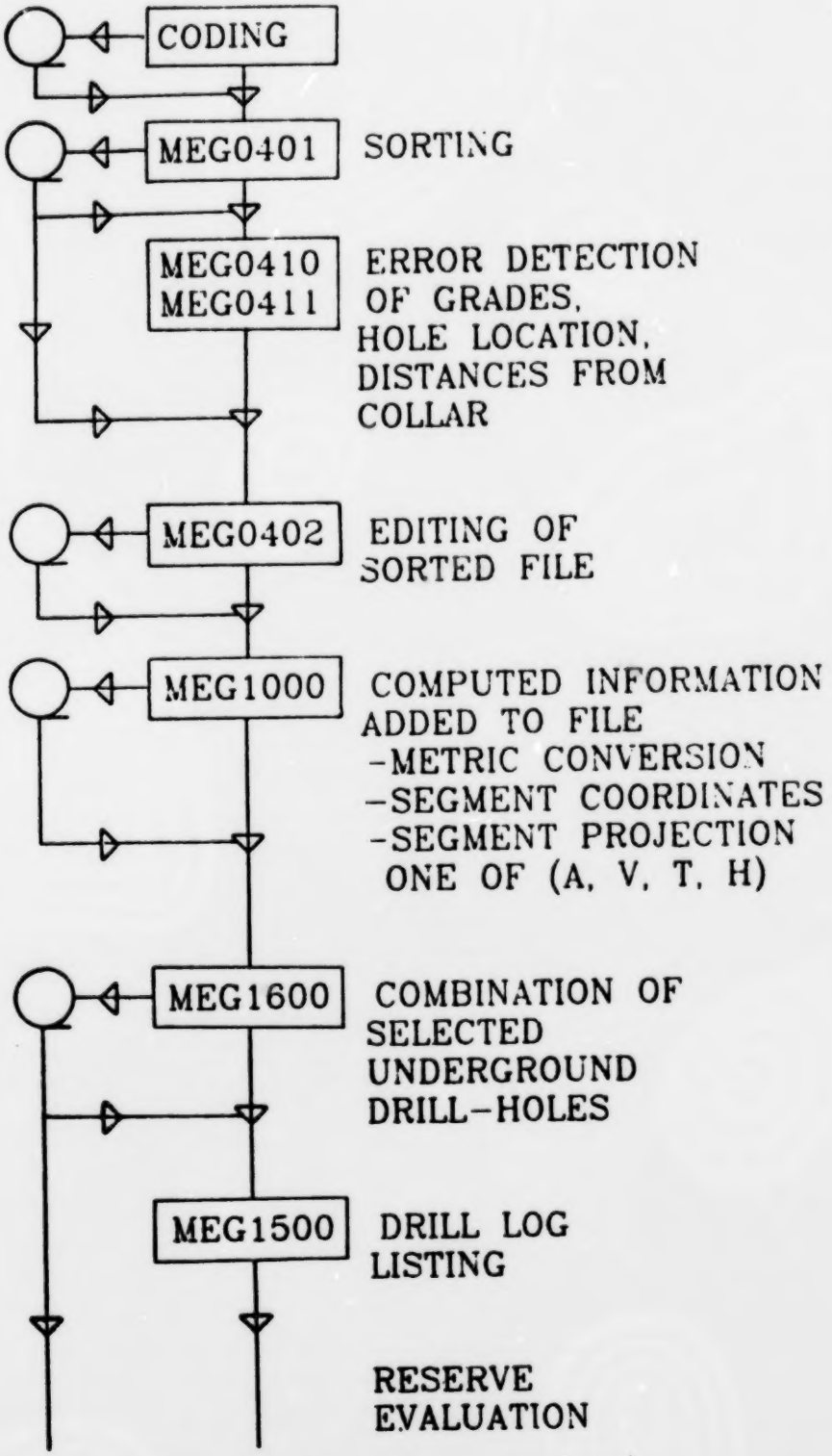


Fig. 2 - CADD system organizational chart

Table 1 - Use of GEM system programs with different evaluation methodologies

DESCRIPTION OF PROGRAMS			PROGRAM NAME	EVALUATION METHODOLOGY							
				GEOMETRIC METHODS				MOVING AVERAGE AND DISTANCE WEIGHTING METHODS		GEO-STATISTICAL METHODS	
				SECTION		POLYGON					
TABULAR DEPOSITS		2-D		2D	3D	2D	3D	2D	3D	2D	3D
ALL DEPOSITS		3-D									
CADD		DATA PREPARATION	1000 1600	☐	☐	☐	☐	☐	☐	☐	☐
GEM SYSTEM	GROUP NO. 1	ECONOMICAL INTERSECTIONS	100	☐	☐	☐		☐		☐	
		GROUPING ECONOMICAL INTERSECTIONS	2010			☐		☐		☐	
		GRAPHICAL PROJECTION OF DRILLHOLES ON SECTION OR PLAN	3000	☐	☐	☐	☐				
	GROUP NO. 2	EQUAL LENGTH SEGMENTS ALONG DRILLHOLES	2040				☐		☐		☐
		GROUPING EQUAL LENGTH SEGMENTS WITHIN UNIT BLOCKS	2050					☐	☐		☐
		EVALUATING BLOCK GRADE USING MOVING AVERAGE OR I.D.	2055					☐	☐		
	GROUP NO. 3	BASIC STATISTICS-HISTOGRAMS DISTRIBUTION TESTS-REGRESSIONS	2100							☐	☐
		VARIOGRAMS AND TRENDS COMPUTED BY THE SECTORS METHOD	2200							☐	☐
		VARIOGRAMS AND TRENDS COMPUTED BY THE BLOCKING METHOD	2250							☐	☐
		TREND AND GENERALIZED COVARIANCE ANALYSIS	2350							☐	
	GROUP NO. 4	NORMAL-LOGNORMAL-CLUSTER-UNIVERSAL POINT-BLOCK-POLYGON-KRIGING	2300							☐	☐
		NORMAL-UNIVERSAL-POINT-BLOCK KRIGING	2350							☐	
		TABLES OF RESERVES INVENTORY	2400							☐	☐
		ISOCURVES TRACING	2500			☐	☐	☐	☐	☐	☐

R0100 ANALYSIS OF DRILL-HOLE DATA 10/09/82 MEG DRILL-HOLE NUMBER ZZX0038 PAGE 1

COMBINED WITH ZZX0039
COMPANY DRILL HOLE NUMBER 77032
SPECIAL DRILL-HOLE IDENT.
DRILLING STARTED 15/10/77
DRILLING COMPLETED 15/10/77

LOCATION UNDERGROUND HOLE . 200 LEVEL . K ZONE

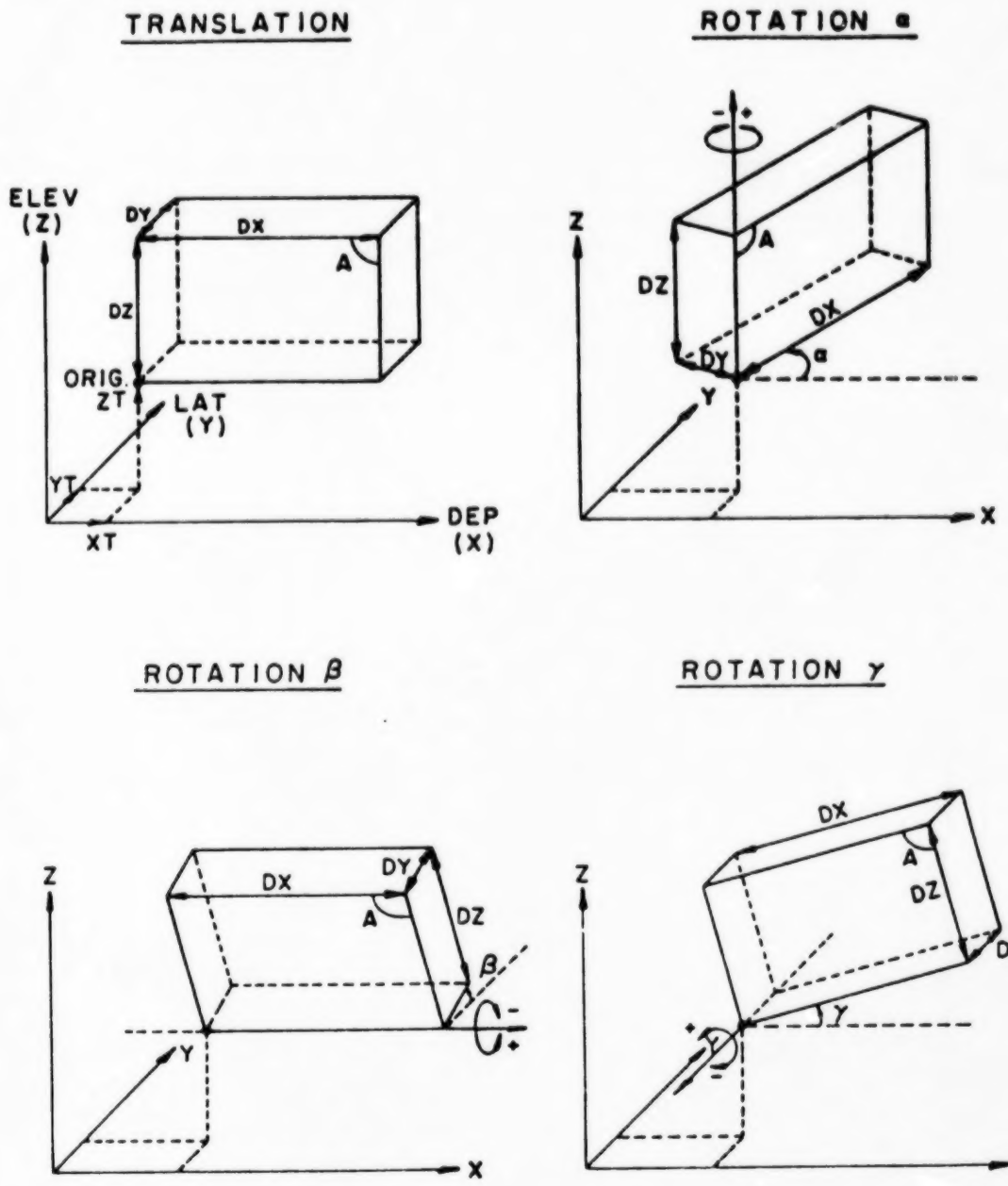
DEPARTURE 7600.00
LATITUDE 8540.00
COLLAR ELEVATION 1210.50
HOLE LENGTH 244.30
DIP OF HOST FORMATION -60
AZIMUTH OF DIP OF H.F. 170

DDH TYPE AXT
HOLE DIAMETER (INCHES) 0.000
INITIAL CASING TYPE
INITIAL CASING LENGTH 0.00
FINAL CASING TYPE
FINAL CASING LENGTH 0.00
NUMBER OF SEGMENTS 58

U308 CUT-OFF GRADE 3.00
MIN. MINING WIDTH 10.00
MIN. WASTE THICKNESS 0.00
MAX. DIL. WIDTH 0.00
TCP CUT WIDTH 0.00
ZONE(S) ALL

SAMPLE NUMBER	S W	DIST. FROM COLLAR	SEGMENT THICKNESS APPAR.	APPAR.	SEGMENT DIP	AZI.	P C	PERC. CORE. REC.	A C T M	U308 GRADE	C M. G O.DE I I.II	DILUTED/MINED-OUT PORTION U308 AVG. DIL.	U308 GRADE MINED	METAL PER UNIT AREA GROSS DIL.	GROSS MINED	NET DIL.	NET MINED	THICKNESS DIL.	THICKNESS MINED	ID D	ID M
	3	172.10	17.10	17.10	0	180		100	0	0.00	-										
	3	155.00	3.90	3.90	0	180		100	0	0.00	-										
	0	151.10	1.60	1.60	0	180		0	0	0.00	-										
	3	149.50	13.90	13.90	0	180		100	0	0.00	-										
33-18	3	135.60	2.90	2.90	0	180		100	B B	1.22	-										
	3	132.70	47.20	47.20	0	180		100	0	0.00	-										
33-17	3	85.50	1.40	1.40	0	180		100	A B	.68	-										
33-16	3	84.10	1.20	1.20	0	180	P	100	A B	4.34	+	D2	6.61		7.33		3.34		13.30		01
33-15	3	82.90	2.90	2.90	0	180	P	100	A B	12.32	+	D2									
33-14	3	80.00	2.40	2.40	0	180	P	100	A B	12.68	+	D2									
33-13	3	77.60	.90	.90	0	180	P	100	A B	.10	-	D2									
	3	76.70	1.70	1.70	0	180	P	100	0	0.00	-	D2									
33-12	3	75.00	.90	.90	0	180	P	100	A B	3.96	+	D2									
33-12	3	74.10	1.60	1.60	0	180	P	100	A B	3.92	+	D2									
33-12	3	72.50	1.70	1.70	0	180	P	100	B B	3.92	+	D2									
	3	70.80	3.50	3.50	0	180	P	100	0	0.00	-										
33-11	3	67.30	.80	.80	0	180	P	100	A B	5.52	+										
	3	66.50	1.40	1.40	0	180	P	100	0	0.00	-										
33-10	3	64.90	.80	.80	0	180	P	100	A B	8.76	+										
33-9	3	64.10	1.90	1.90	0	180		100	A B	.92	-										
	3	62.20	11.00	11.00	0	180		100	0	0.00	-										
	3	51.20	1.30	1.30	0	180		100	0	0.00	-										
	3	49.90	.80	.80	0	180		100	0	0.00	-										
	3	49.10	4.50	4.50	0	180		100	0	0.00	-										
	3	44.60	16.30	16.30	0	180		100	0	0.00	-										
	3	28.30	.30	.30	0	180		100	0	0.00	-										
	3	28.00	3.20	3.20	0	180		100	0	0.00	-										
33-8	3	24.80	1.10	1.10	0	180		100	A B	.56	-										
33-7	3	23.70	2.10	2.10	0	180		100	A B	1.96	-										
33-6	3	21.60	1.60	1.60	0	180		100	A B	.42	-										
	3	20.00	9.00	9.00	0	180		100	0	0.00	-										
33-5	3	11.00	1.70	1.70	0	180		100	A B	1.28	-										
33-4	3	9.30	2.10	2.10	0	180	K	100	A B	5.94	+	D2	3.79		3.15		.15		10.00		02
33-3	3	7.20	2.20	2.20	0	180	K	100	A B	6.16	+	D2									
33-2	3	5.00	1.70	1.70	0	180	K	100	A B	1.04	-	D2									
33-1	3	3.30	3.30	3.30	0	180	K	100	A B	2.43	-	D2									
	S 1	-.00	.70	.70	0	180	K	100	A B	2.96	-	M D2		2.67		2.61		-.90		11.70	01
	S 1	-.70	4.30	4.30	0	180	K	100	A B	2.96	-	M									
	1	-5.00	6.70	6.70	0	180	K	100	A B	2.46	-	M									
	3	-11.70	2.80	2.80	0	180	K	100	C E	0.00	-										
32-1	3	-14.50	3.80	3.80	0	180	K	100	S B	1.56	-										
32-2	3	-18.30	2.10	2.10	0	180	K	100	S B	4.86	+	D1	5.91		8.32		3.25		16.90		03
32-3	3	-20.40	2.80	2.80	0	180	K	100	S B	7.86	+	D1									
32-4	3	-23.20	2.30	2.30	0	180	K	100	S B	9.24	+	D1									

Fig. 3 - Part of MEG0100 output results - identification of economical composite intersections along a drillhole



A Block in Space is Defined by an Origin (XT, YT, ZT), It's Sides (DX, DY, DZ) and Three Angles of Rotation (α, β, γ). The Information Inside the Block is Projected on Plane (A) by the Computer Program. Positive Angles are Counter Clockwise.

Fig. 4 - MEG3000 basic methodological description

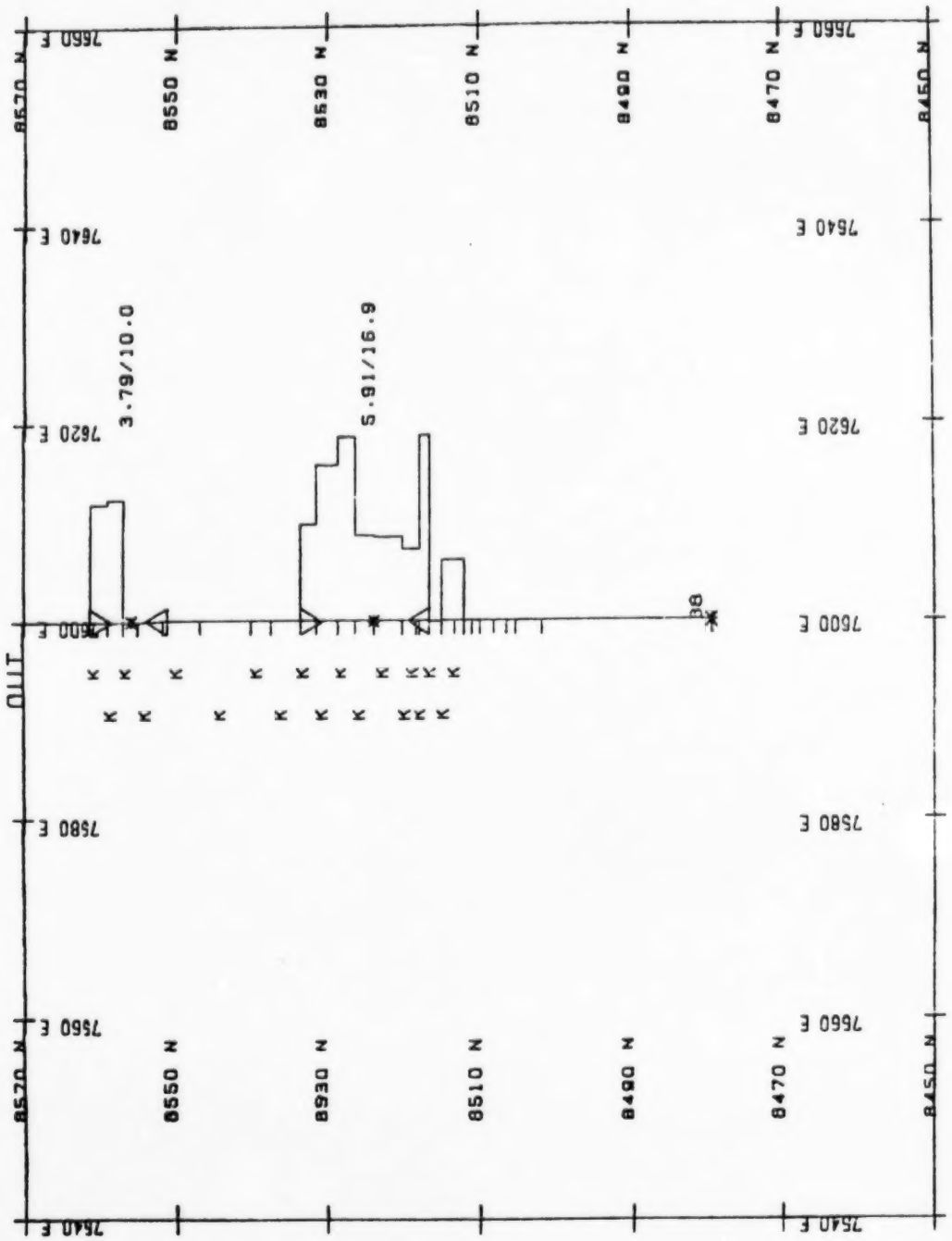


Fig. 5 - MEG3000 out result - plan showing a horizontal drillhole

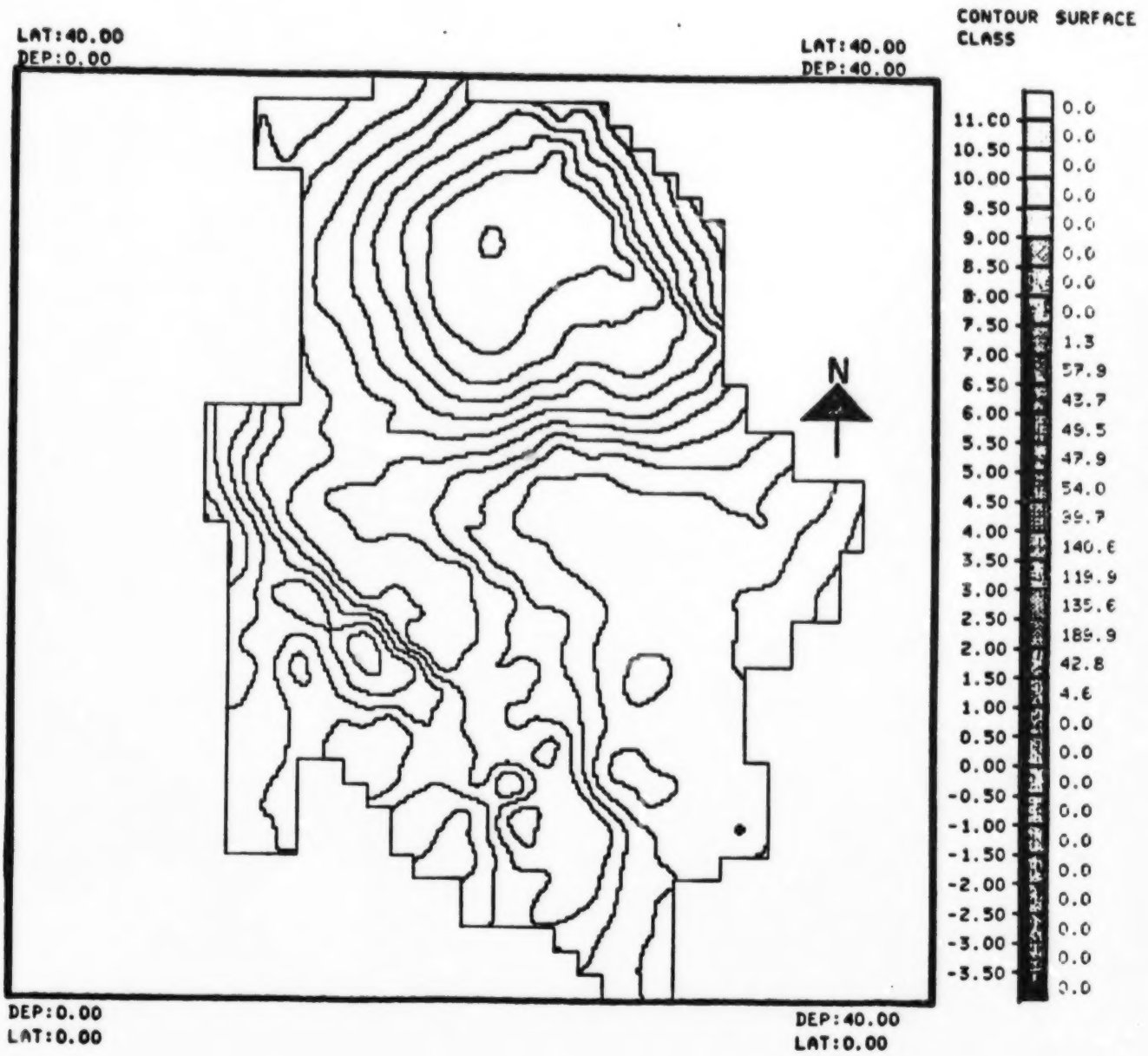


Fig. 6 - MEG2560 output result - isocurves giving net coal thicknesses